Solar Wind Induced Substrate Alteration on Genesis Array Materials and H^+ Diffusion at L1

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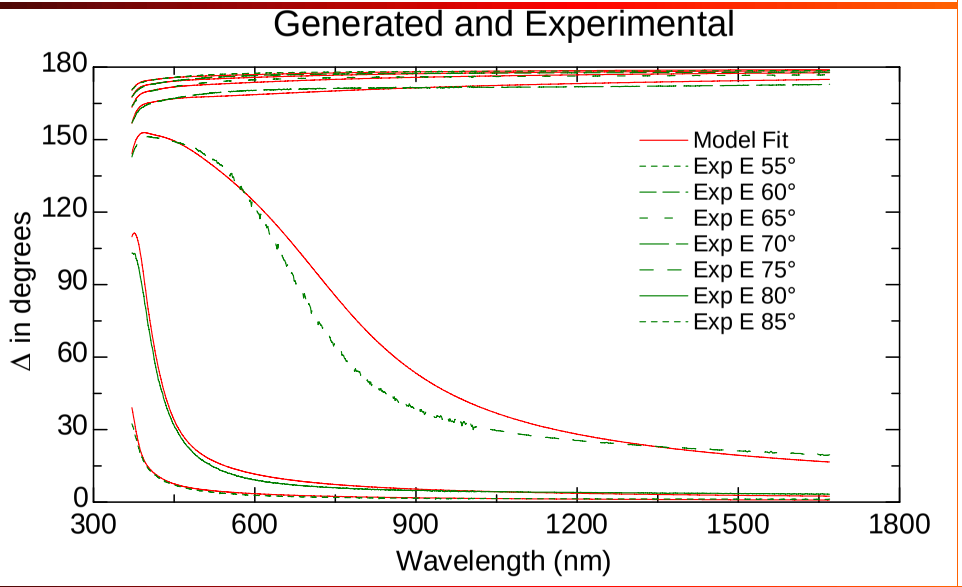
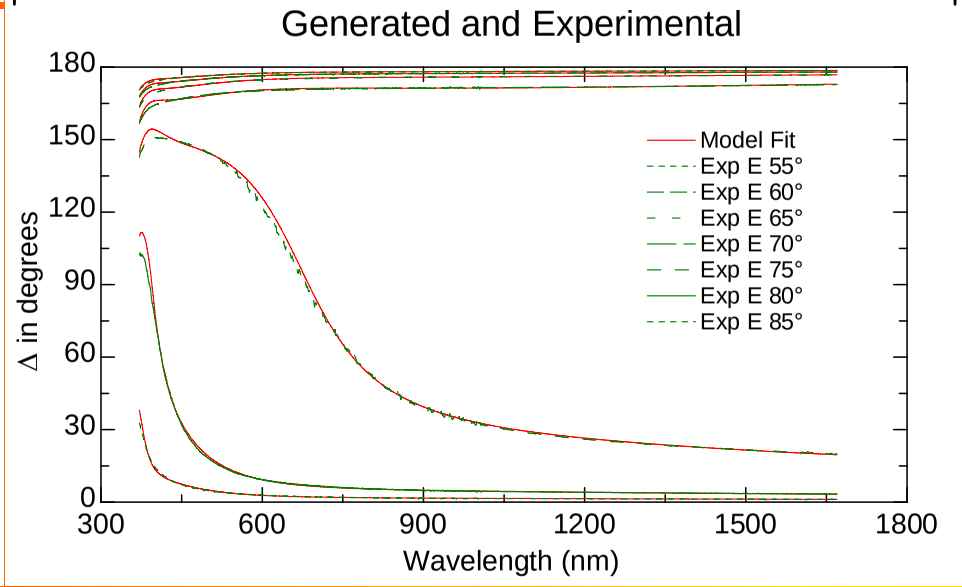
Review of Si Ellipsometry Results (Presented at 2006 LPSC)

- **Effective Medium Approximation (EMA) Layer used to model lattice void spaces.**
- **EMA layer model suggests solar wind radiation zone depth.**

1	sio2_jaw	37.36 Å
0	si_jaw	1 mm



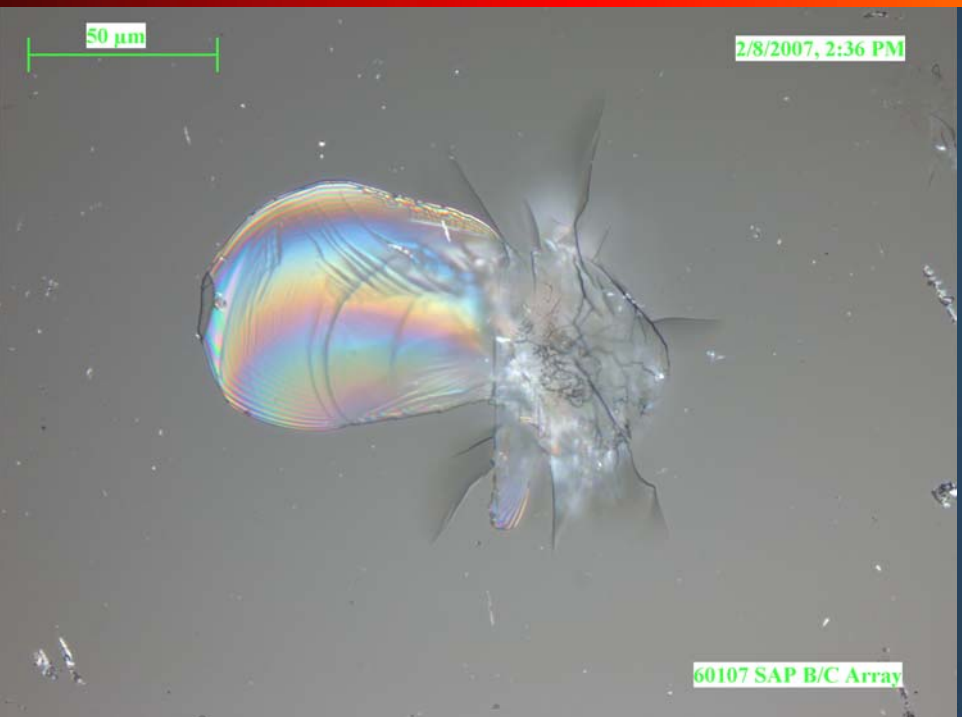
3	sio2_jaw	33.91 Å
2	EMA (si_jaw)/1.34% void	611.41 Å
1	si_jaw	0.00 Å
0	si_jaw	1 mm



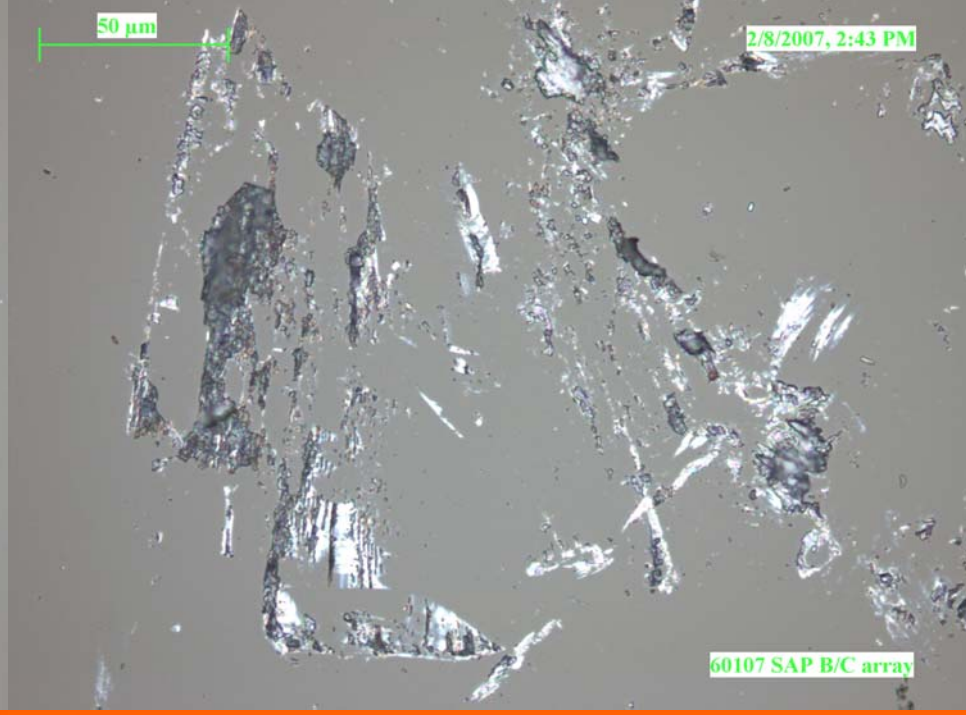
Sample 60208 Flown Genesis Si B/C array

Review of Surface Contamination after UPW/Megasonic Treatment

- Molecular Contamination (Brown stain remains)
- Very little surface particle contamination remains
- UPW treatment does remove some statically charged particles
- Impact Craters still have small particles around craters
- Melted and fused materials are not removed
- Fused materials are 90 % other wafer fragments
- Still Unknown Contamination




50 µm
2/8/2007, 2:40 PM
60107 SAP B/C array


50 µm
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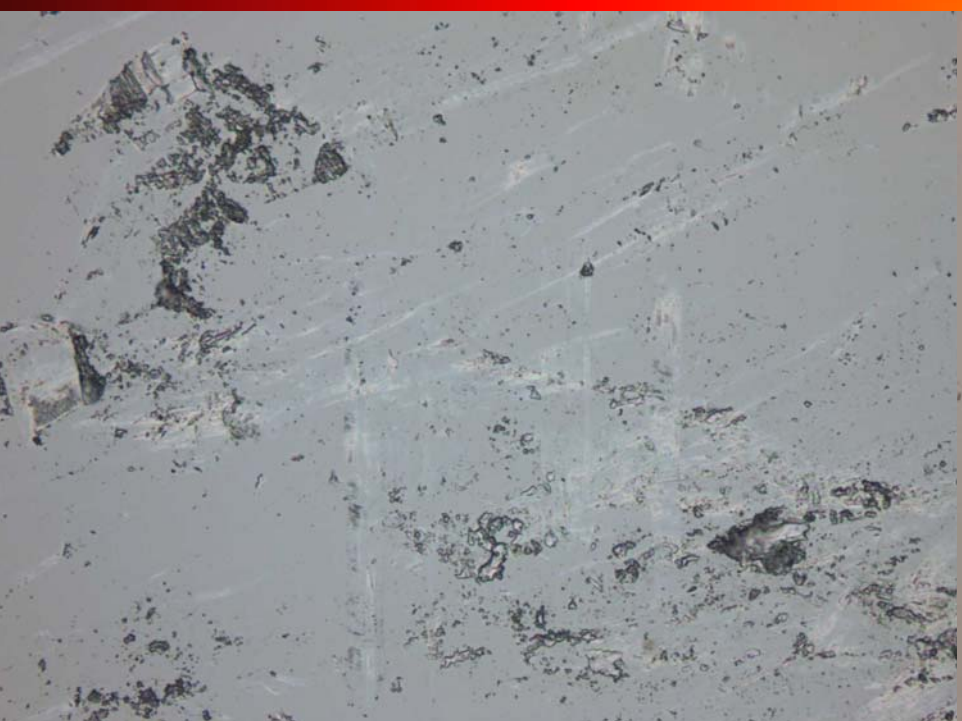
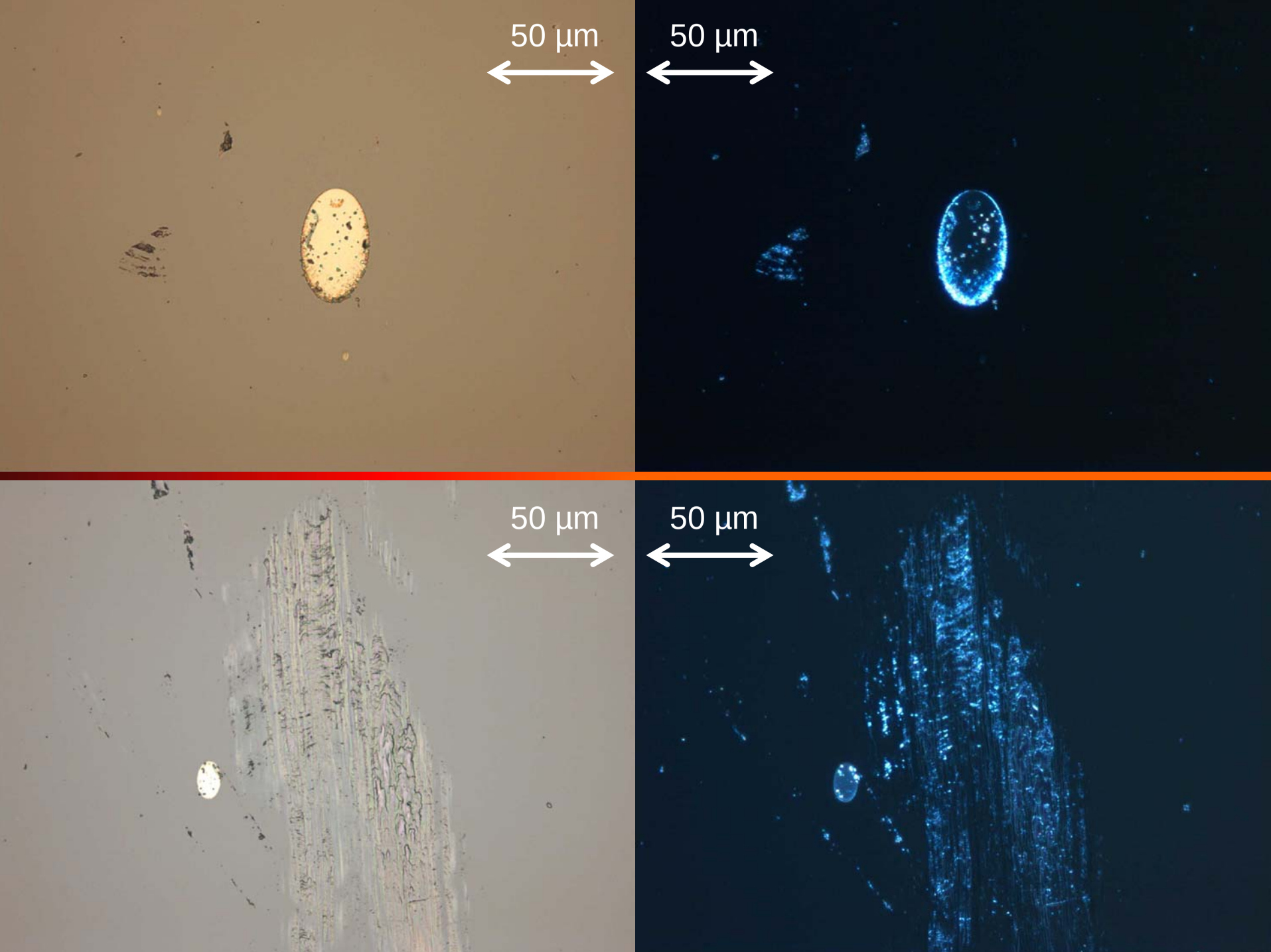
60107 SAP B/C array

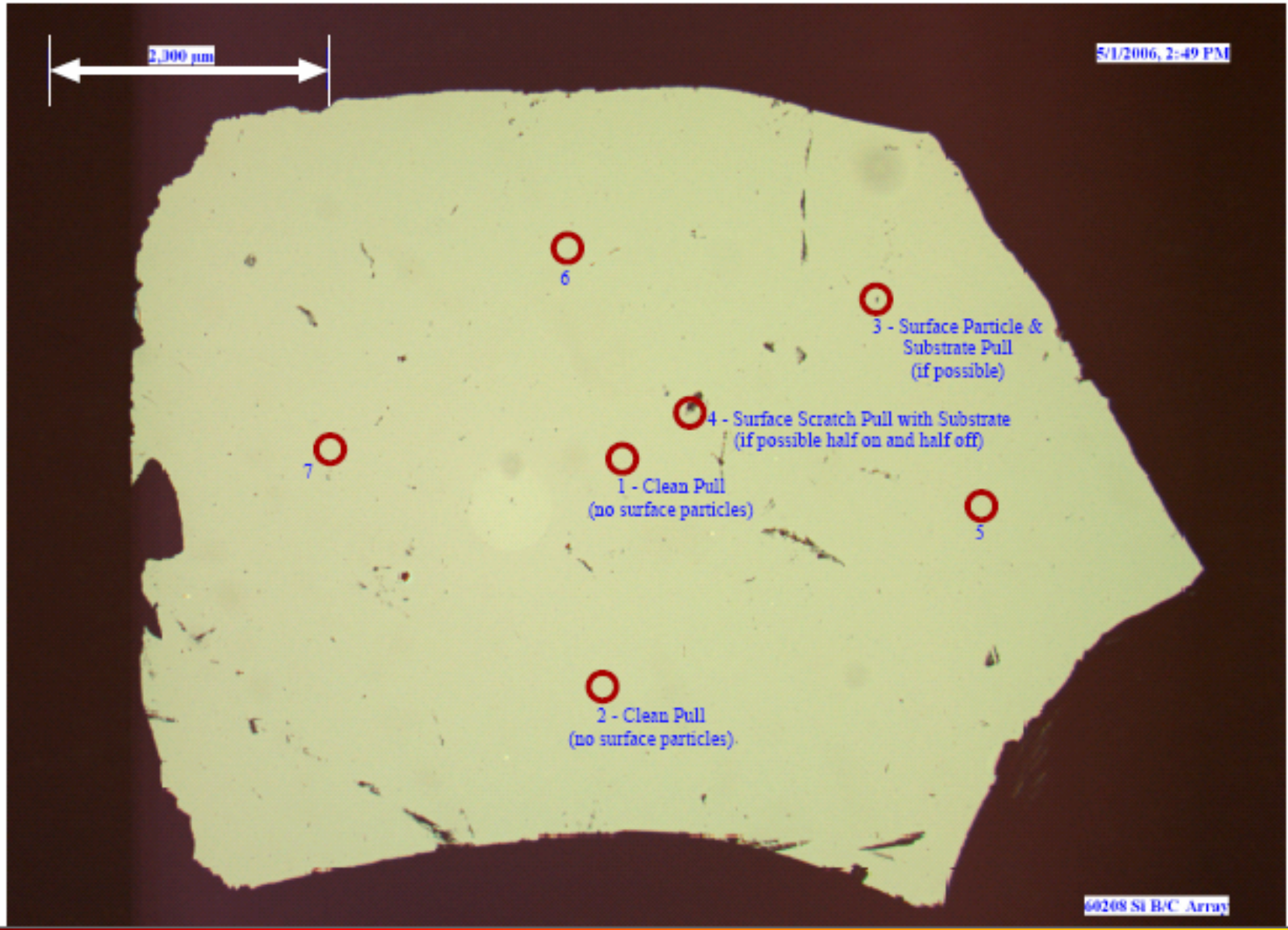



50 µm
50 µm
50 µm
50 µm

STEM Study Objectives

- Characterize the Brown Stain and any other thin film contamination.
- Characterize (if possible) surface particle contamination and the interaction with the wafer surface.
- Characterize the native oxide layer and verify ellipsometry thickness results.
- Verify ellipsometry EMA layer model for Silicon and substrate alteration thickness.
- Did the Silicon substrate experience lattice alteration during flight?

FIB Pull Locations for Stratigraphic Profiles



Ellipsometry Results for 60208

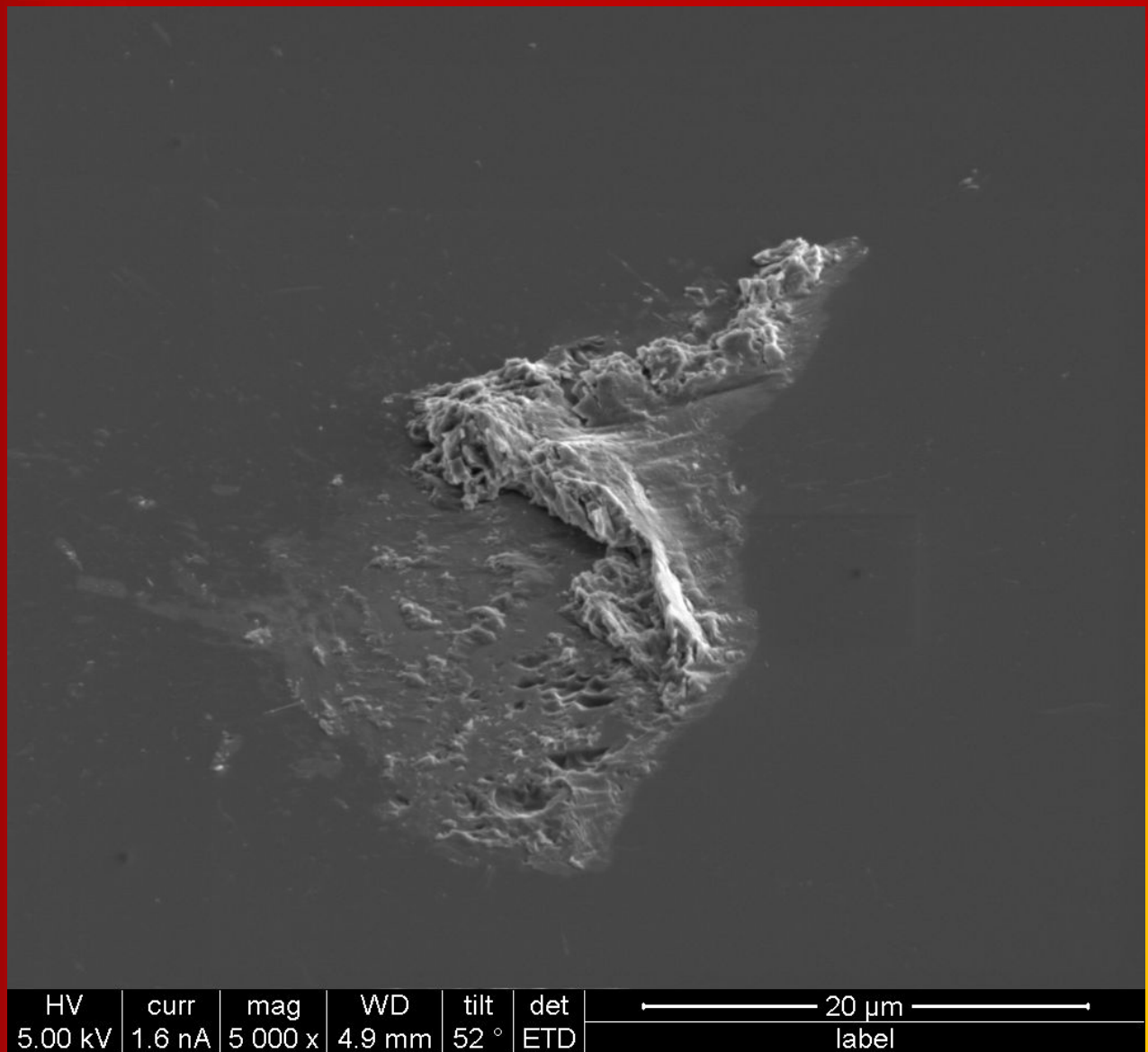
Measurement Location	Gain	Intensity	EMA (Å)	Cauchy (Å)	Native Oxide (Å)	Brown Stain (Å)	MSE
JAWstd Before	8	5.11	N/A	266.42	N/A	N/A	3.475
Before UPW	8	4.43	564.70 ±1.73	43.81 ±0.0702	18	25.81	7.979
Spot 1	8	3.60	604.19 ±1.17	32.06 ±0.037	18	14.06	4.38
Spot 2	8	3.56	602.65 ±1.42	32.64 ±0.0397	18	14.64	4.234
Spot 3	8	4.90	604.86 ±1.25	31.59 ±0.0397	18	13.59	4.828
Spot 4	8	2.50	622.64 ±4.86	32.80 ±0.161	18	14.80	12.91
Spot 5	8	4.70	603.43 ±1.22	32.04 ±0.0382	18	14.04	4.541
JAWstd After	8	5.20	N/A	265.74	N/A	N/A	3.863

Flown Si B/C Array Sample 60208; 5.78 X 7.69 mm; 35.03 mm^2

Cleaning: UPW/Megasonic at 40º C for 5 min. at 1 MHz oscillations

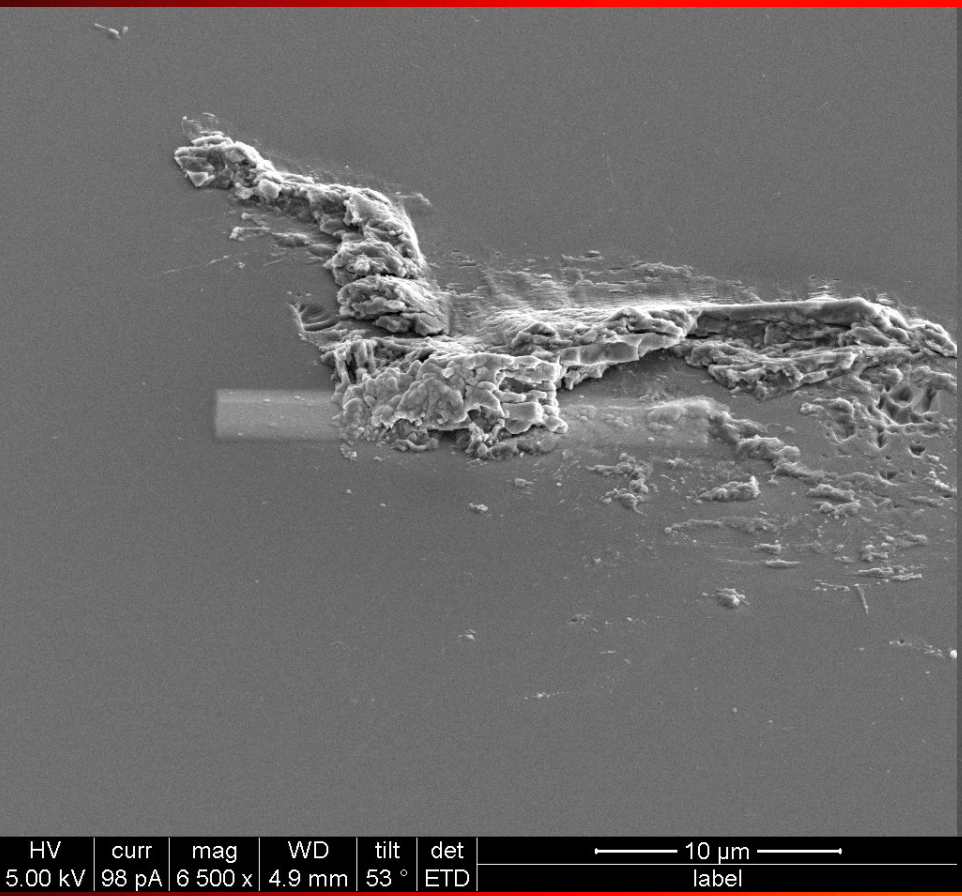
Spot 1 to 5 are after UPW cleaning and Spot 4 had edge effects during run

FIB Startigraphic Cross-section Pull
Sample 60208.4 (Surface particle Pull)

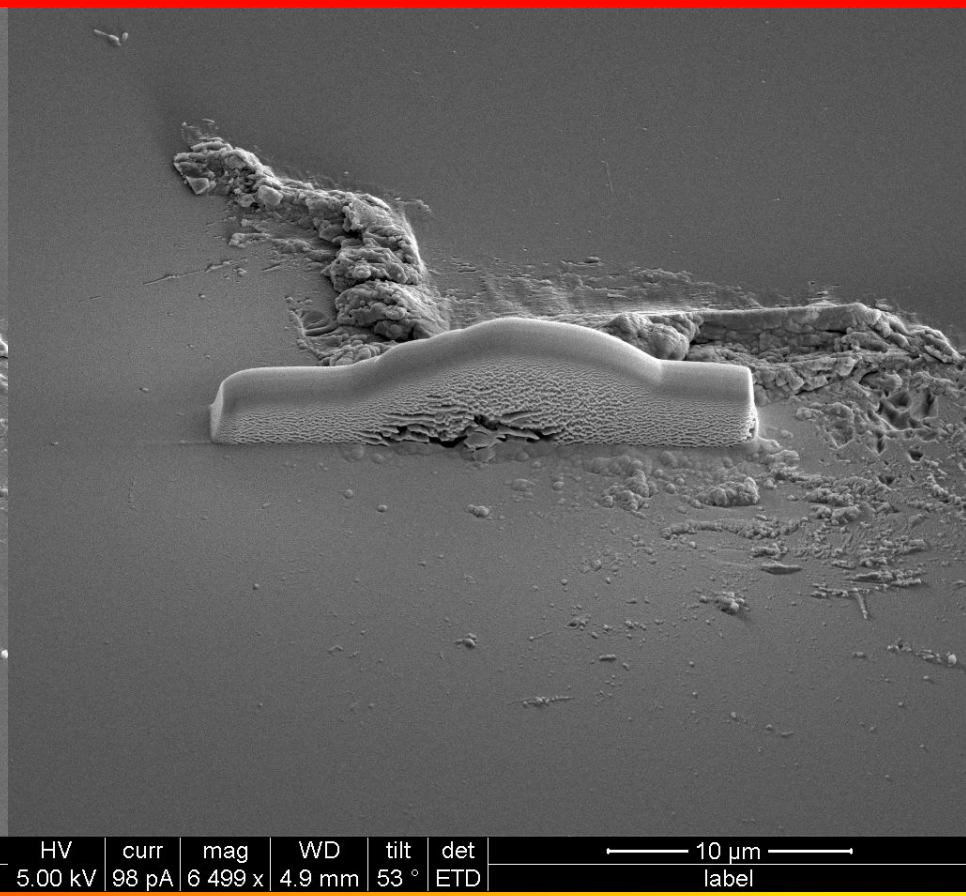


Platinum Coating FIB Pull Section

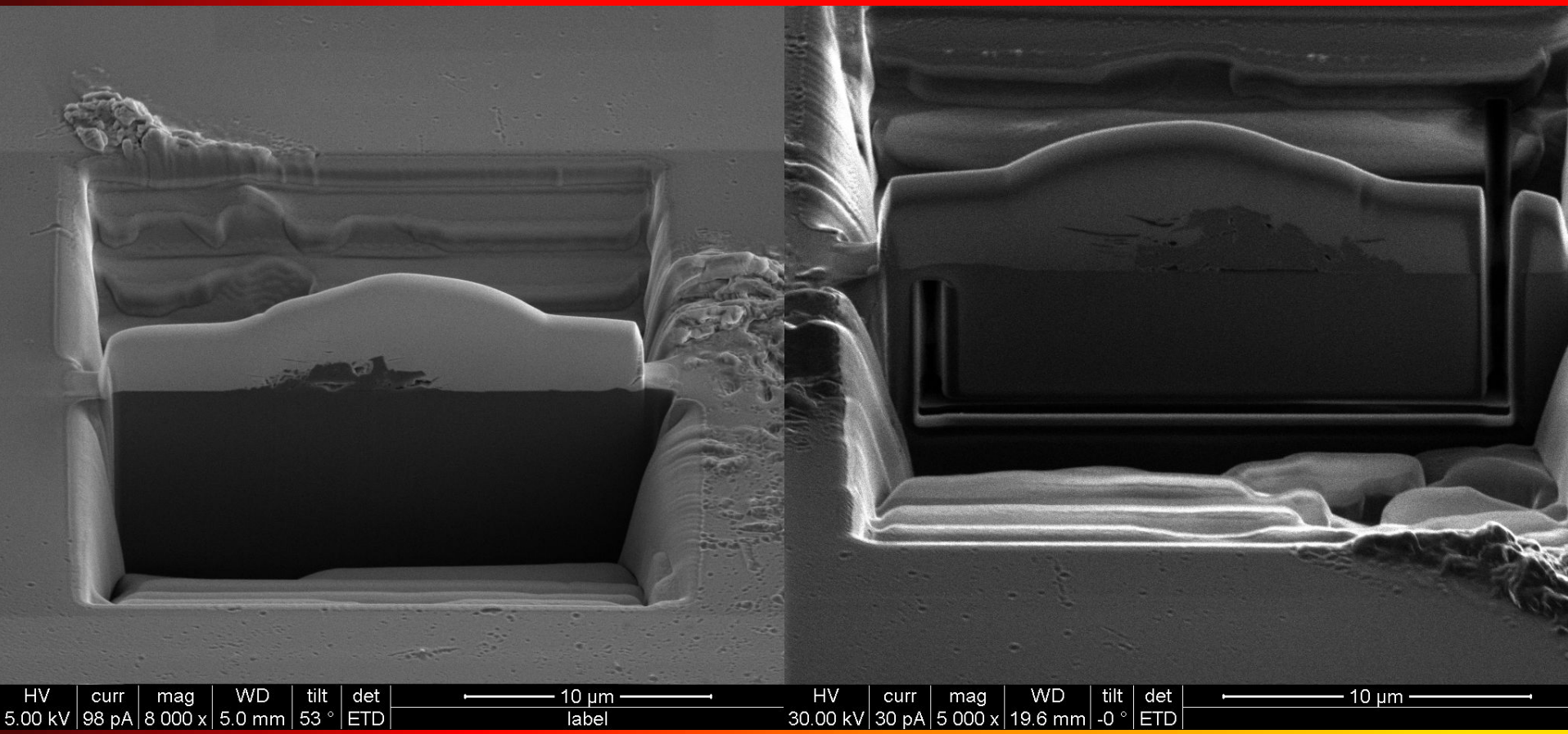
1st Coat



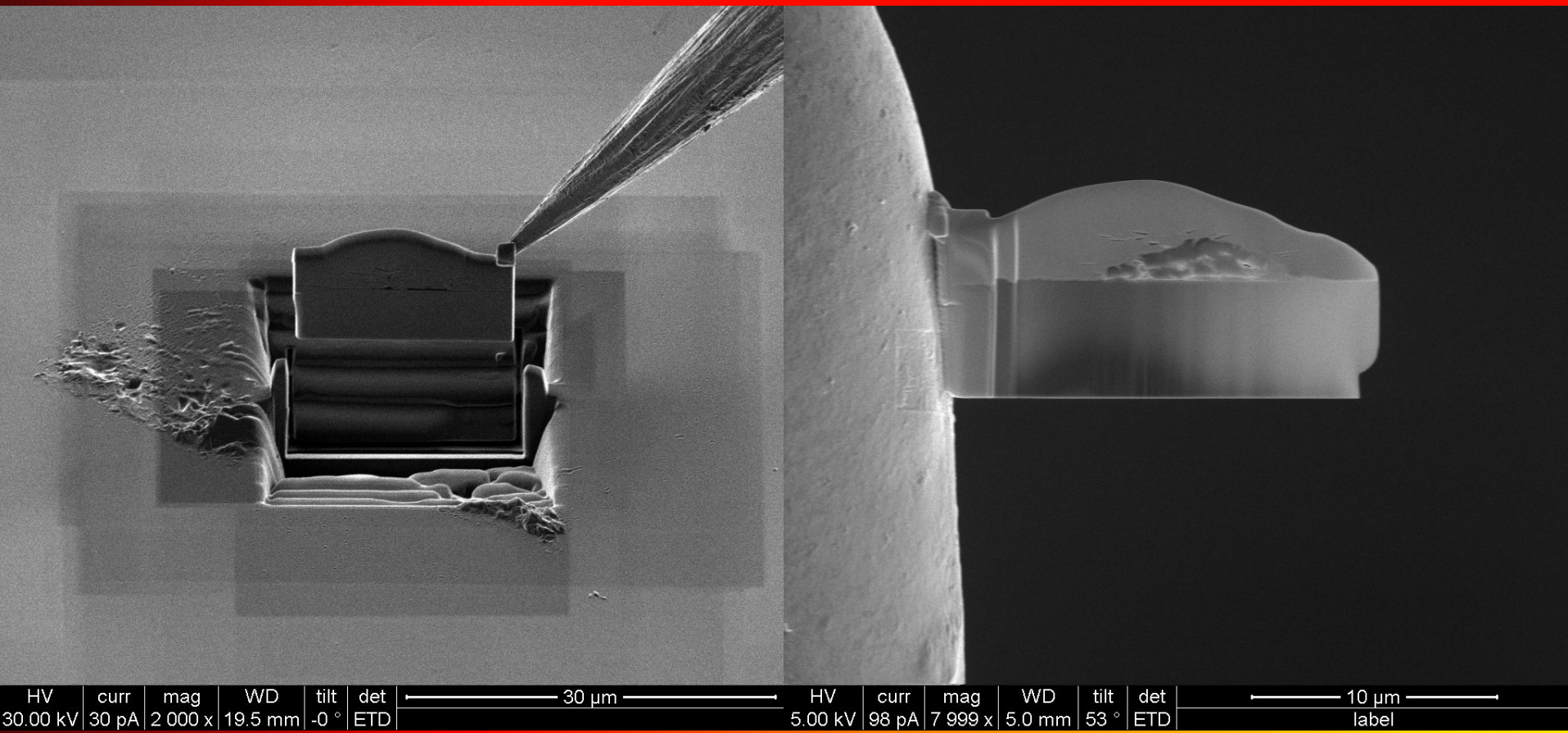
2nd Coat



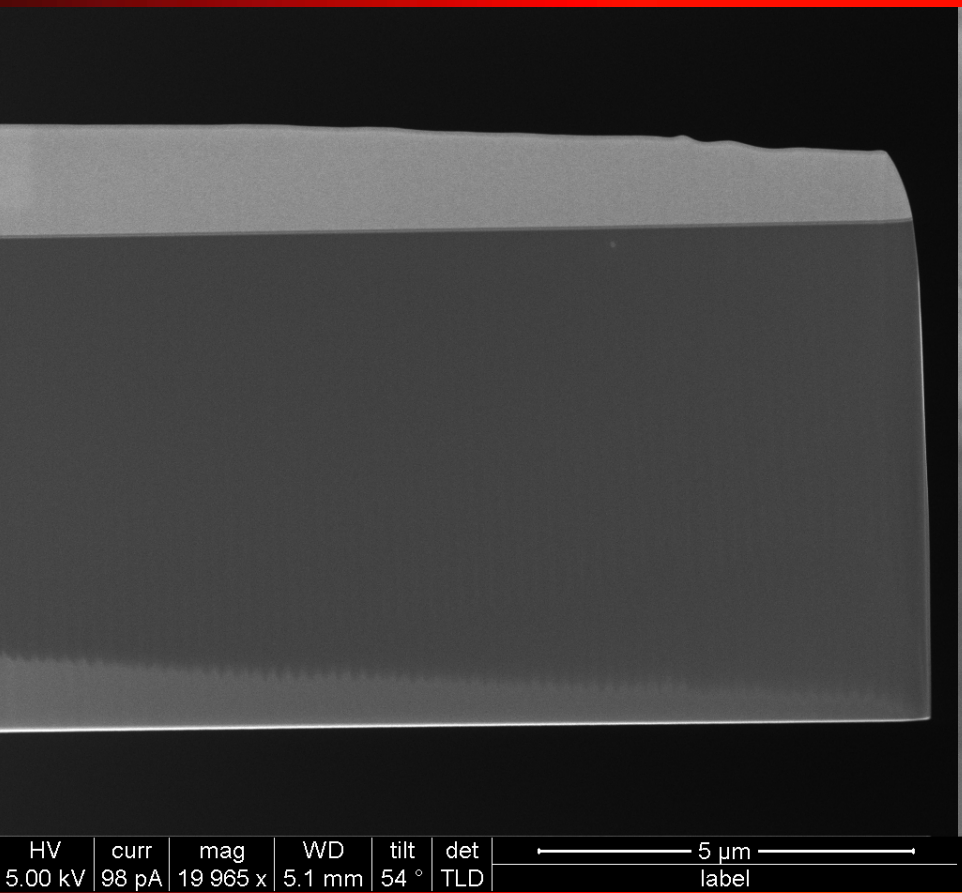
Ion Milling Startigraphic Cross-section

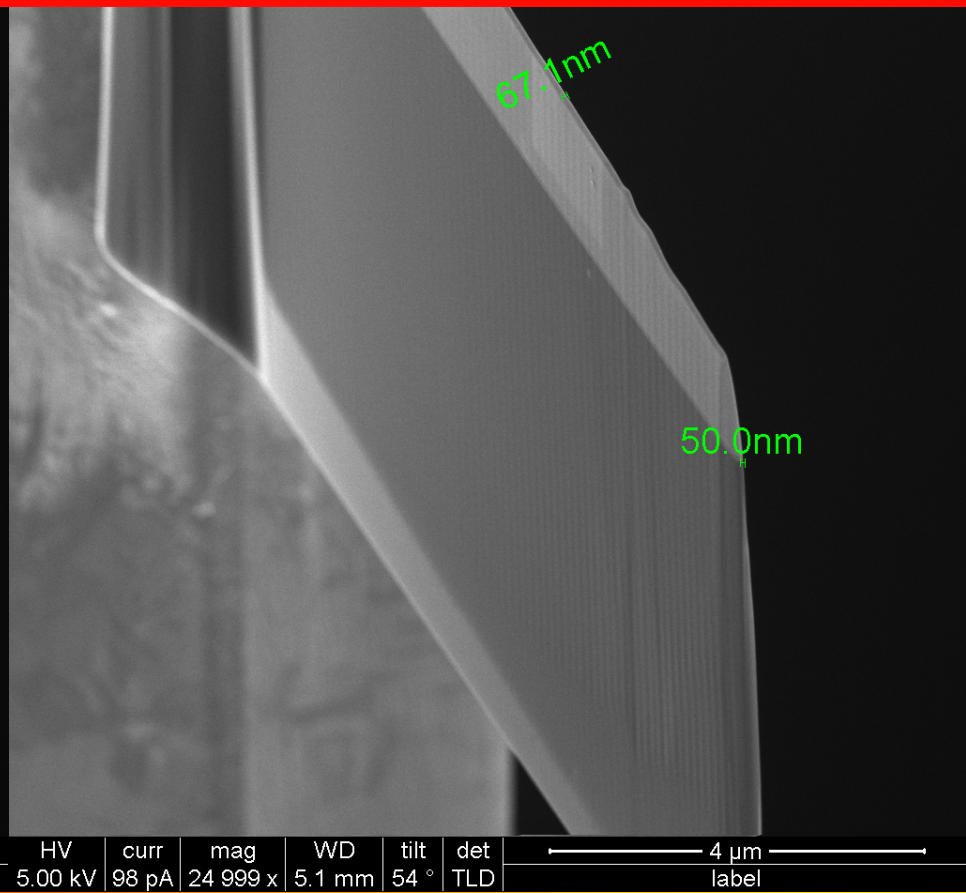


FIB Pull and Mounting Section on TEM Grid



Final Configuration After Polishing
Sample 60208.1
(~ 10 x 6 μm and ~ 60 nm thick)



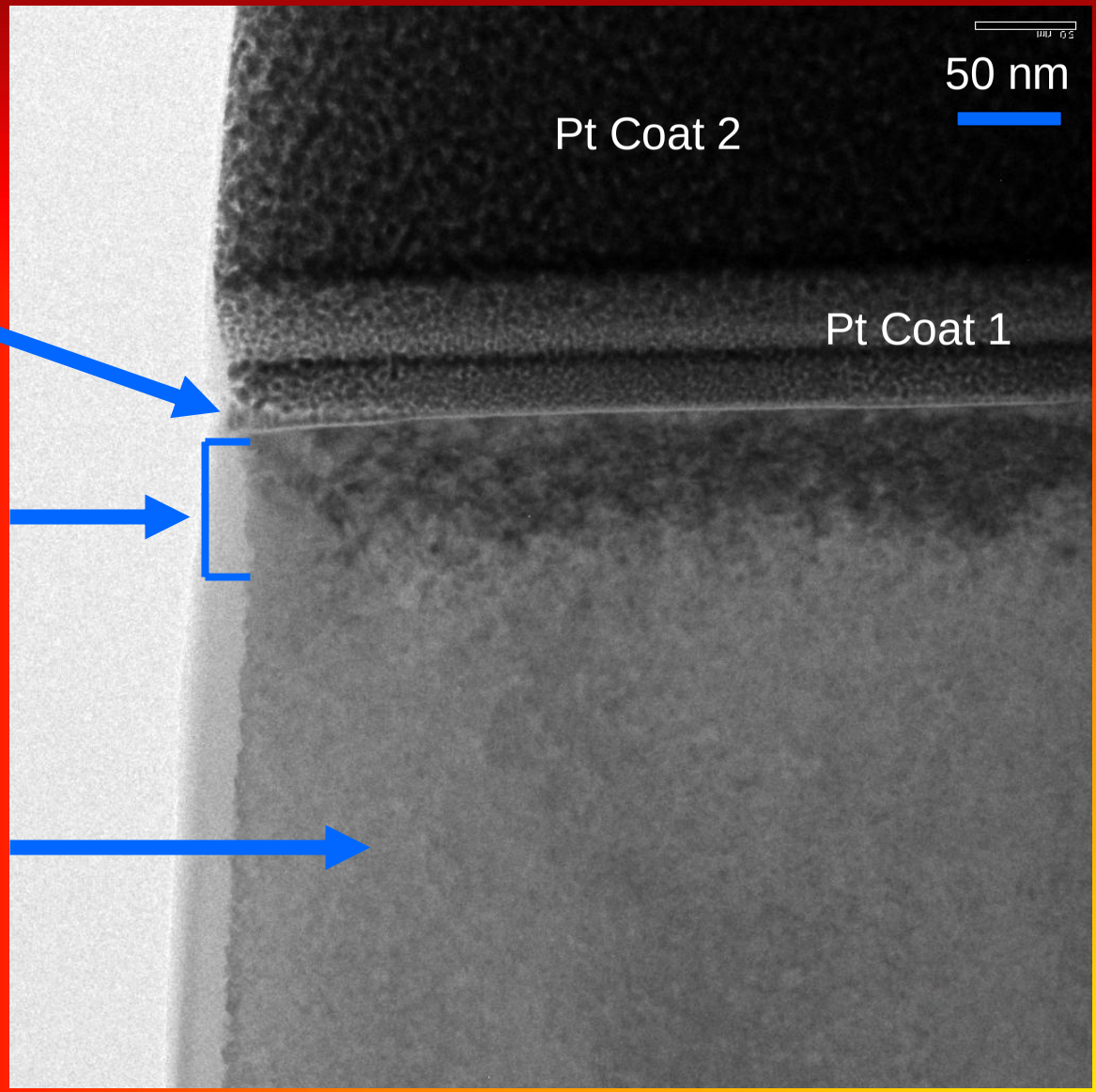


JEOL JEM 2500SE STEM Image of 60208.1 Si B/C Array

Wafer Surface
Native Oxide Layer
SiO_2 = ~ 38 Å

Radiation Damage Zone
Depth = ~ 610 Å

Crystalline Si Substrate



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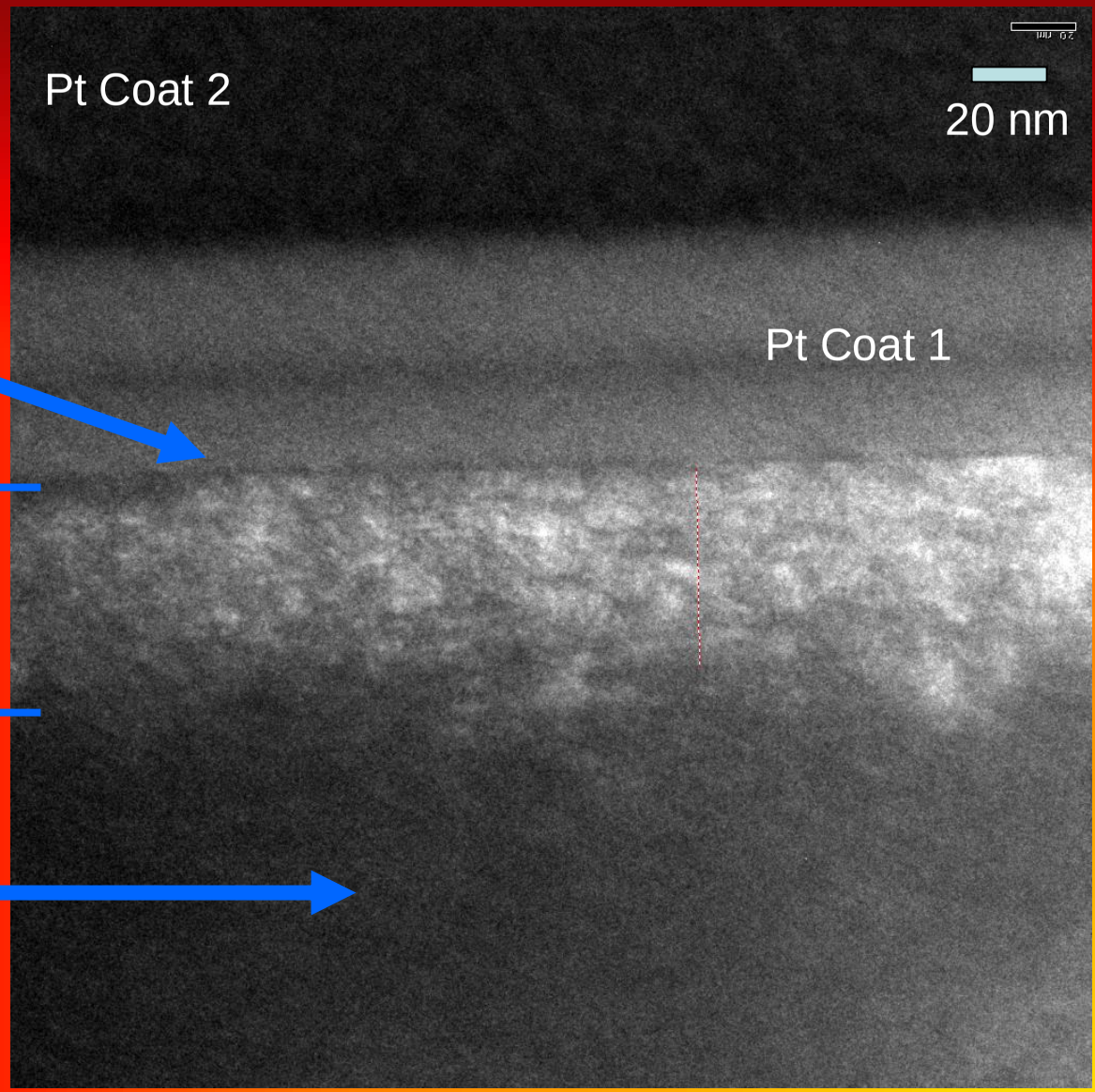
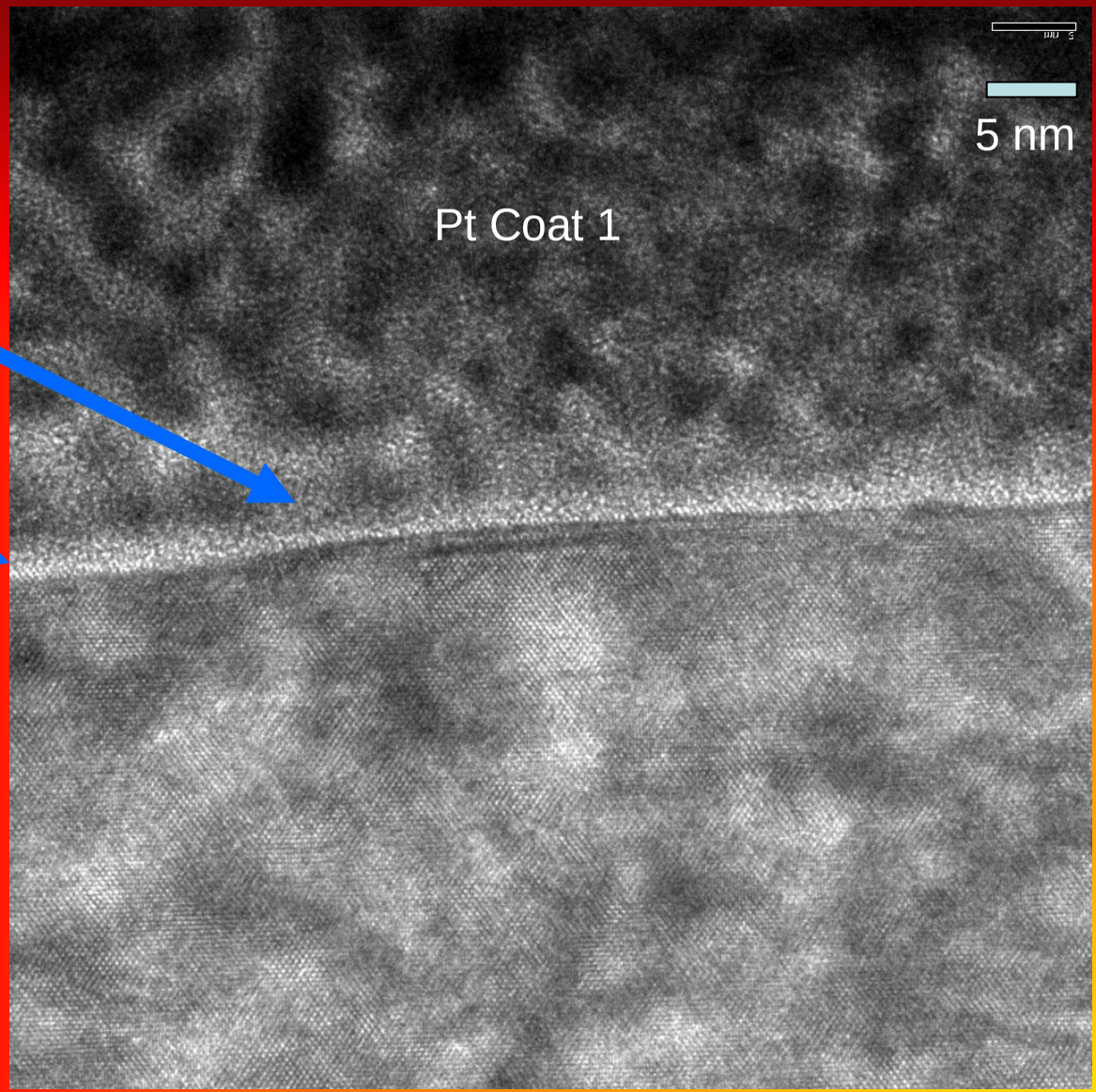


STEM Image of 60208.1 Si B/C Array

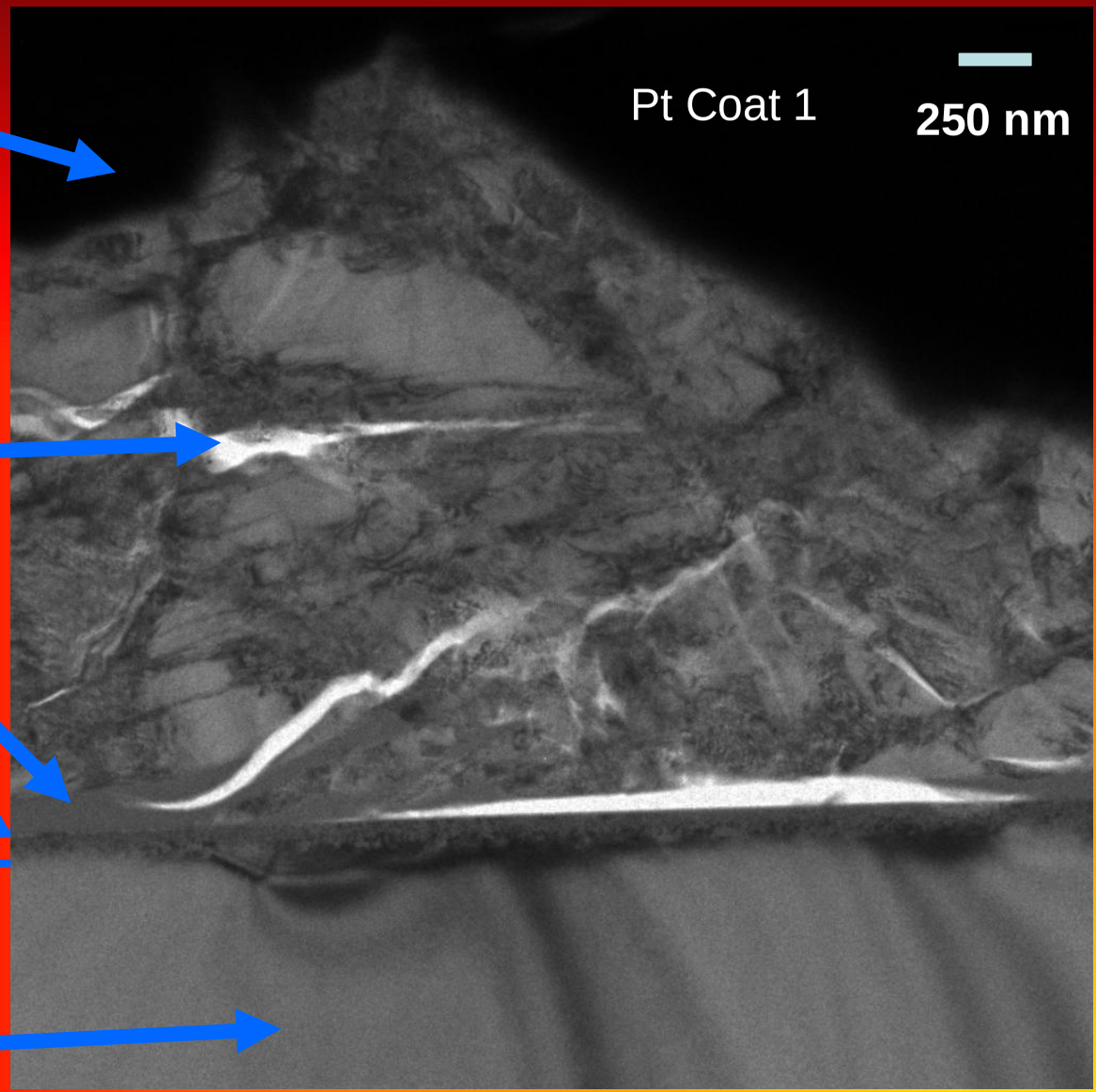


Wafer Surface

Native Oxide Layer
SiO_2 = ~ 38 Å

Radiation Damage Zone

STEM Image of 60208.4 Si B/C Array



c-Si Particle on wafer surface
(EELS spot verification)

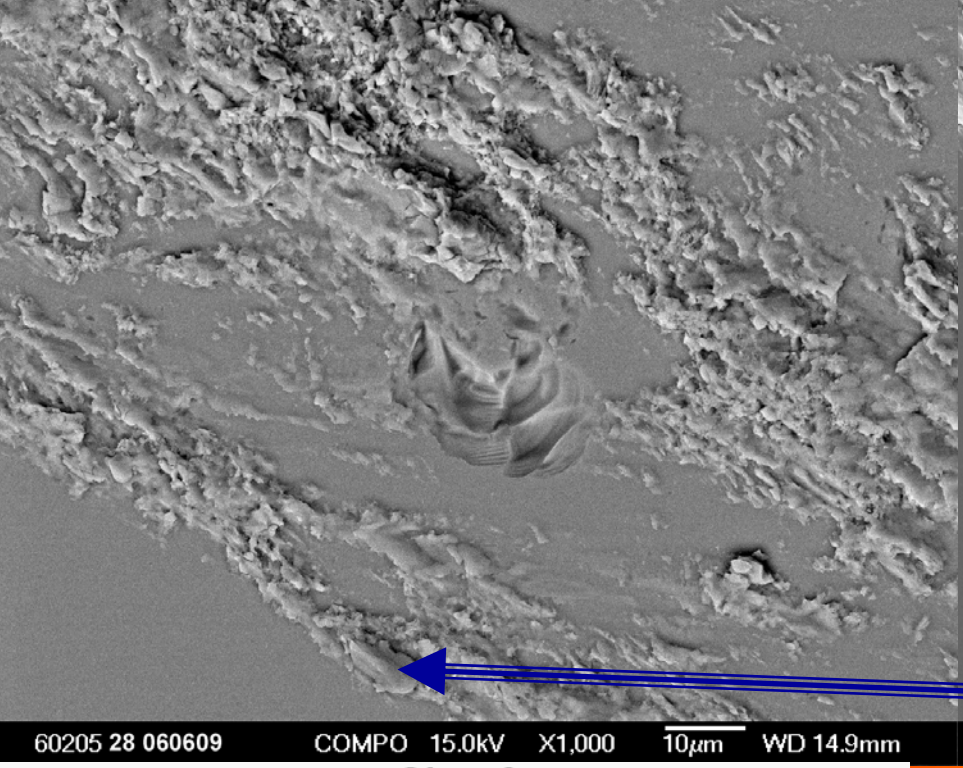
Void Space

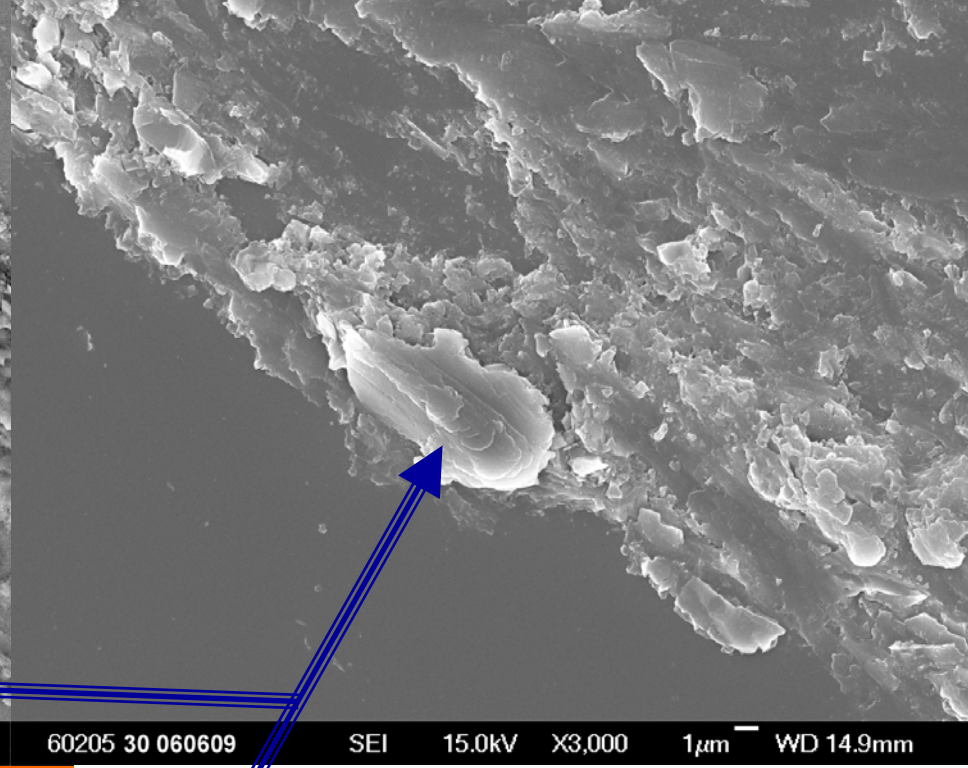
a-Si

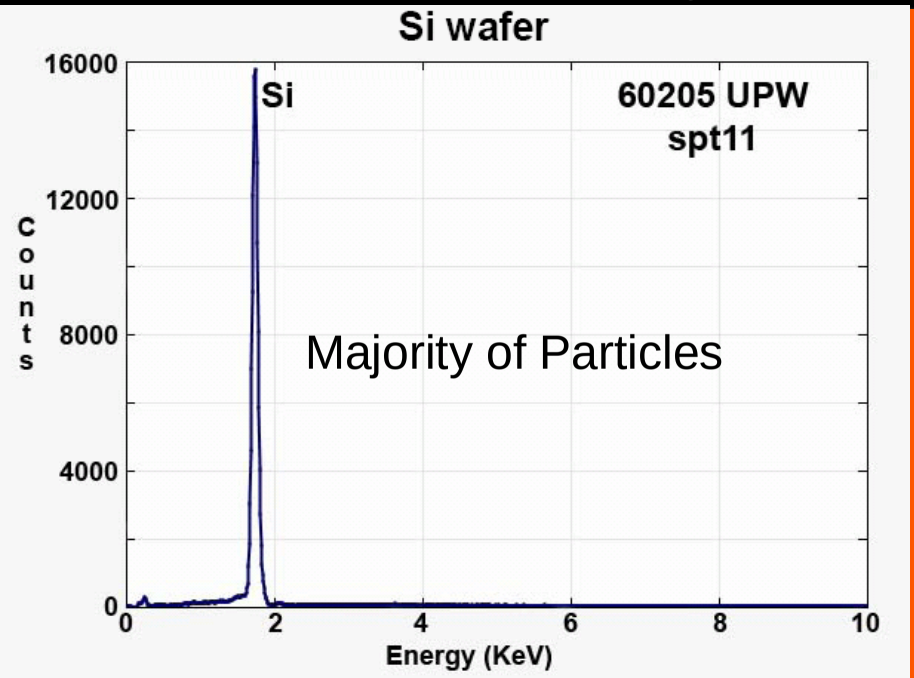
Wafer Surface

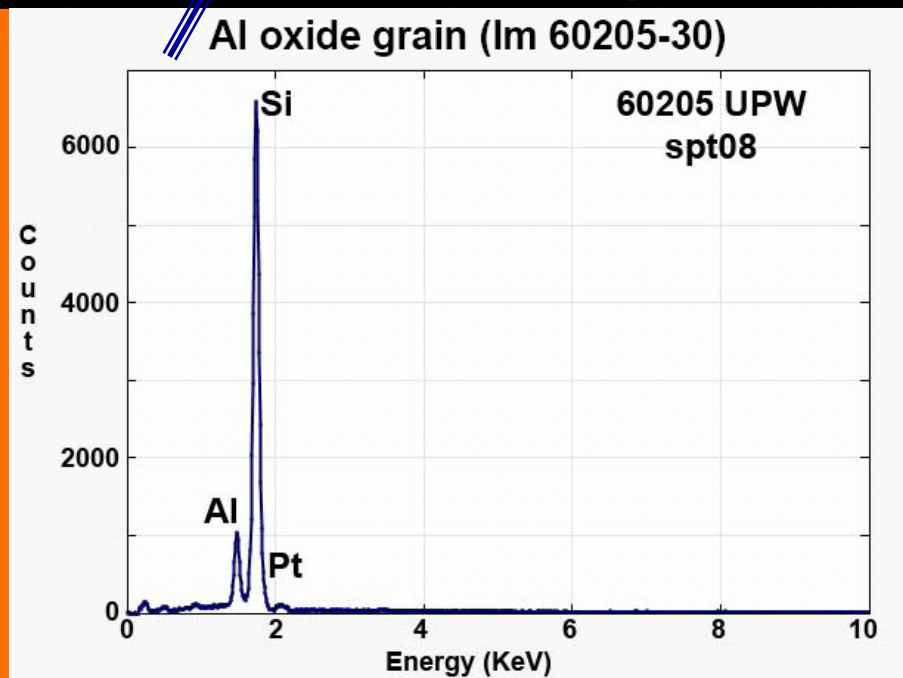
Radiation Damage Zone

c-Si wafer substrate

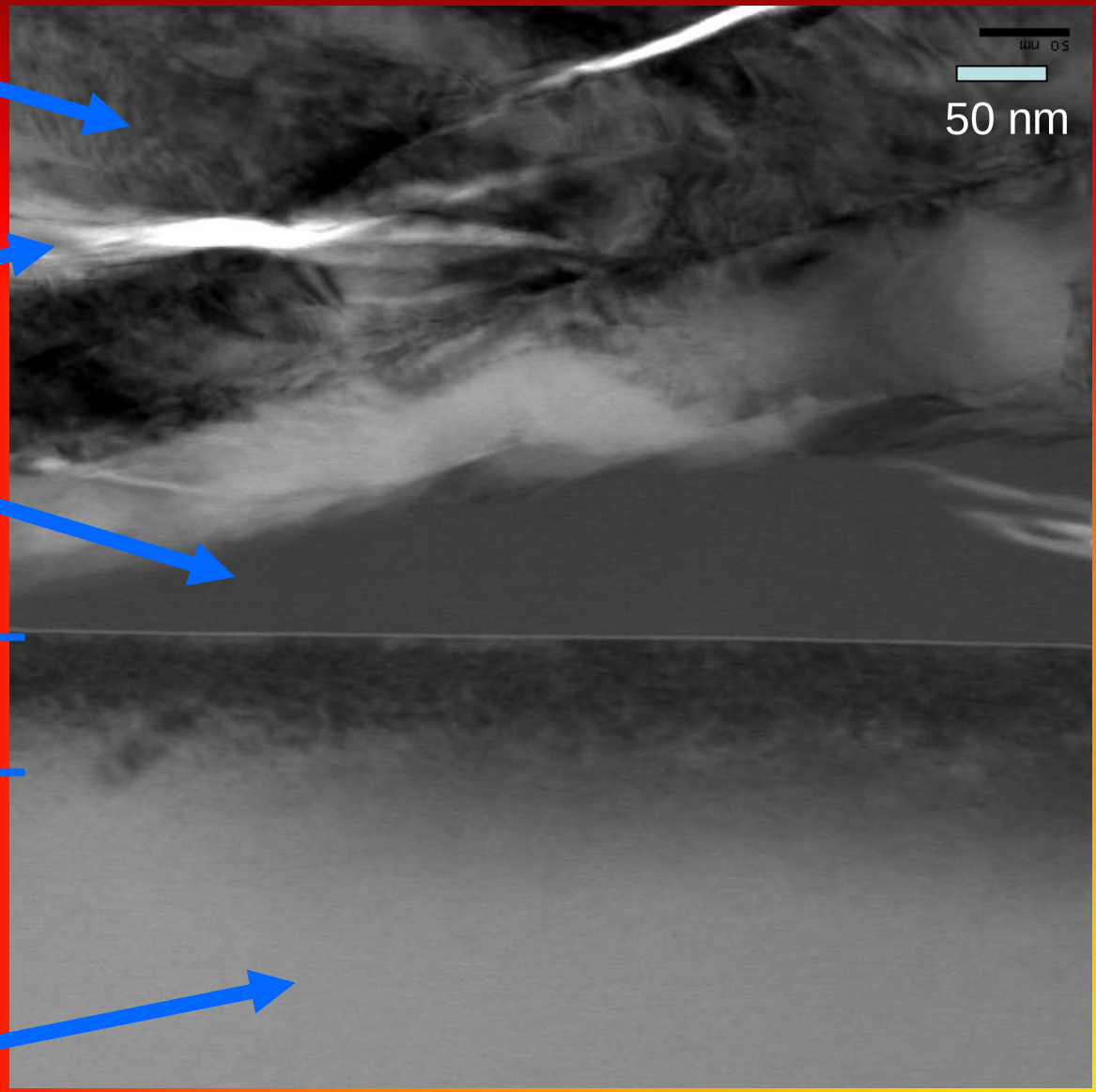

60205 28 060609
COMPO 15.0kV X1,000 10μm WD 14.9mm


60205 30 060609
SEI 15.0kV X3,000 1μm WD 14.9mm


Si wafer
60205 UPW
spt11
Si
Majority of Particles
Counts
Energy (KeV)
0
4000
8000
12000
16000
0
2
4
6
8
10


Al oxide grain (Im 60205-30)
60205 UPW
spt08
Si
Al
Pt
Counts
Energy (KeV)
0
2000
4000
6000
0
2
4
6
8
10

STEM Image of 60208.4 Si B/C Array

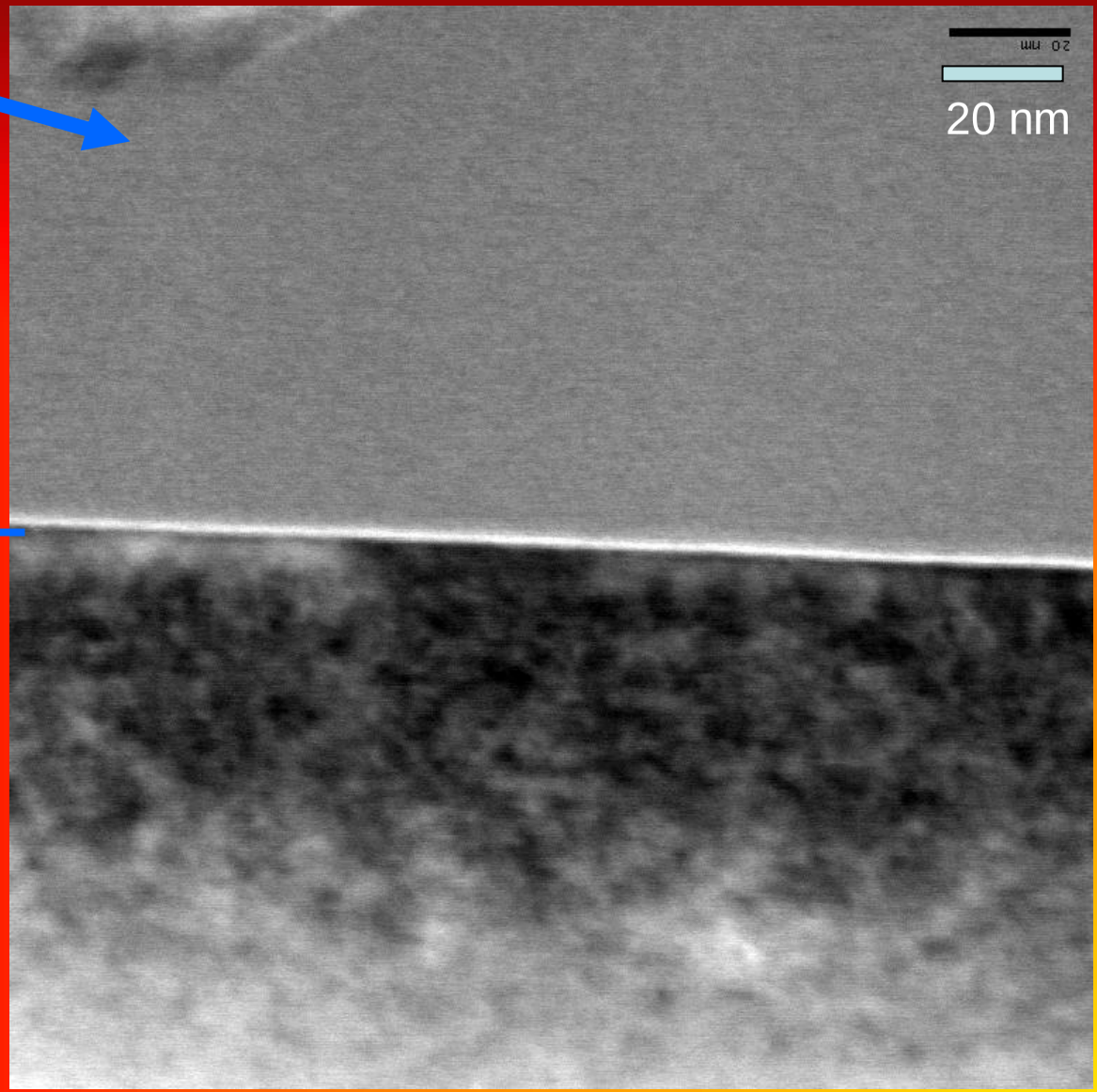


STEM Image of 60208.4 Si B/C Array

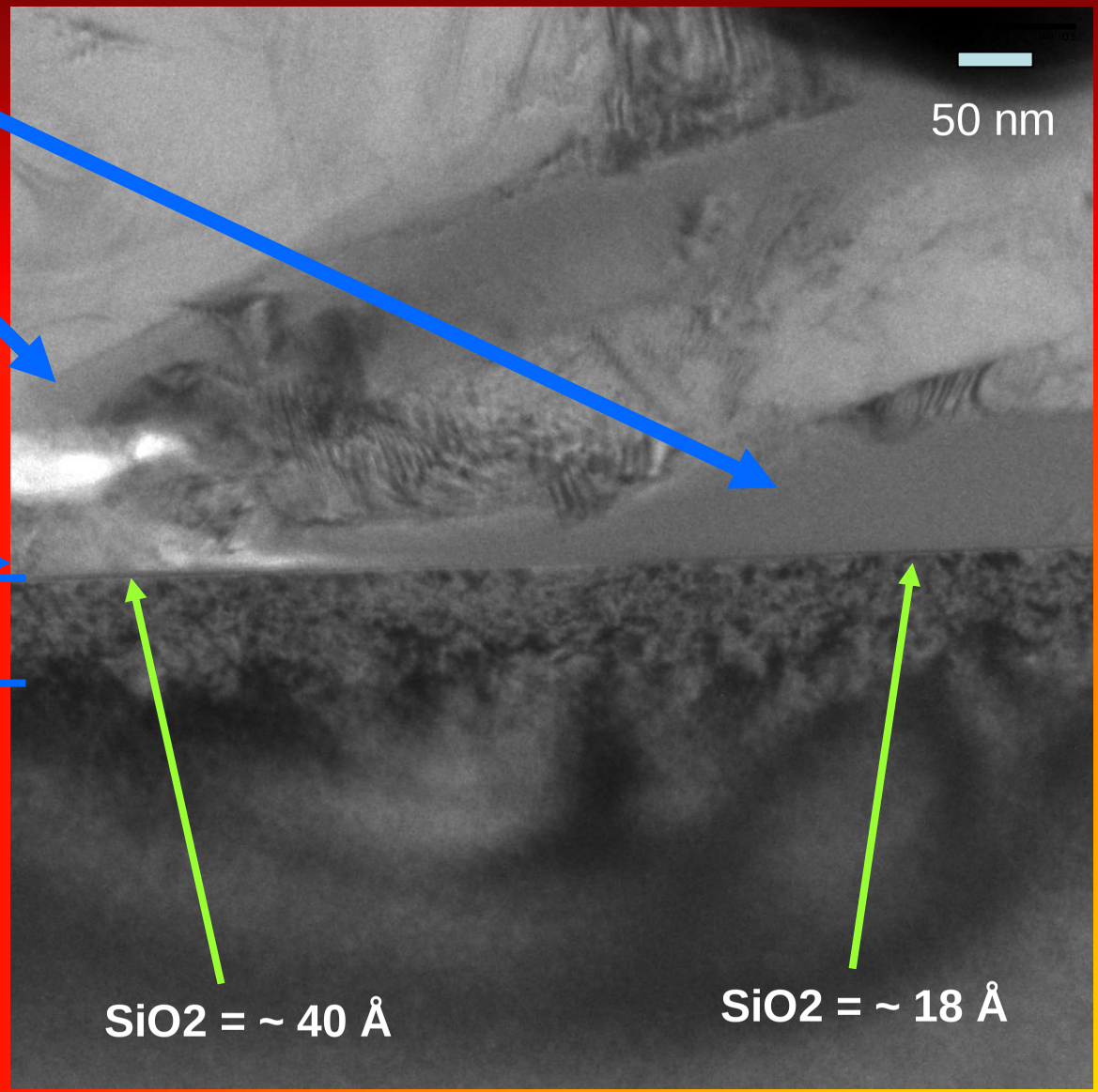
a-Si Particle on wafer surface

Wafer Surface Native Oxide Layer SiO_2 = ~ 18 Å

Radiation Damage Zone



STEM Image of 60208.4 Si B/C Array



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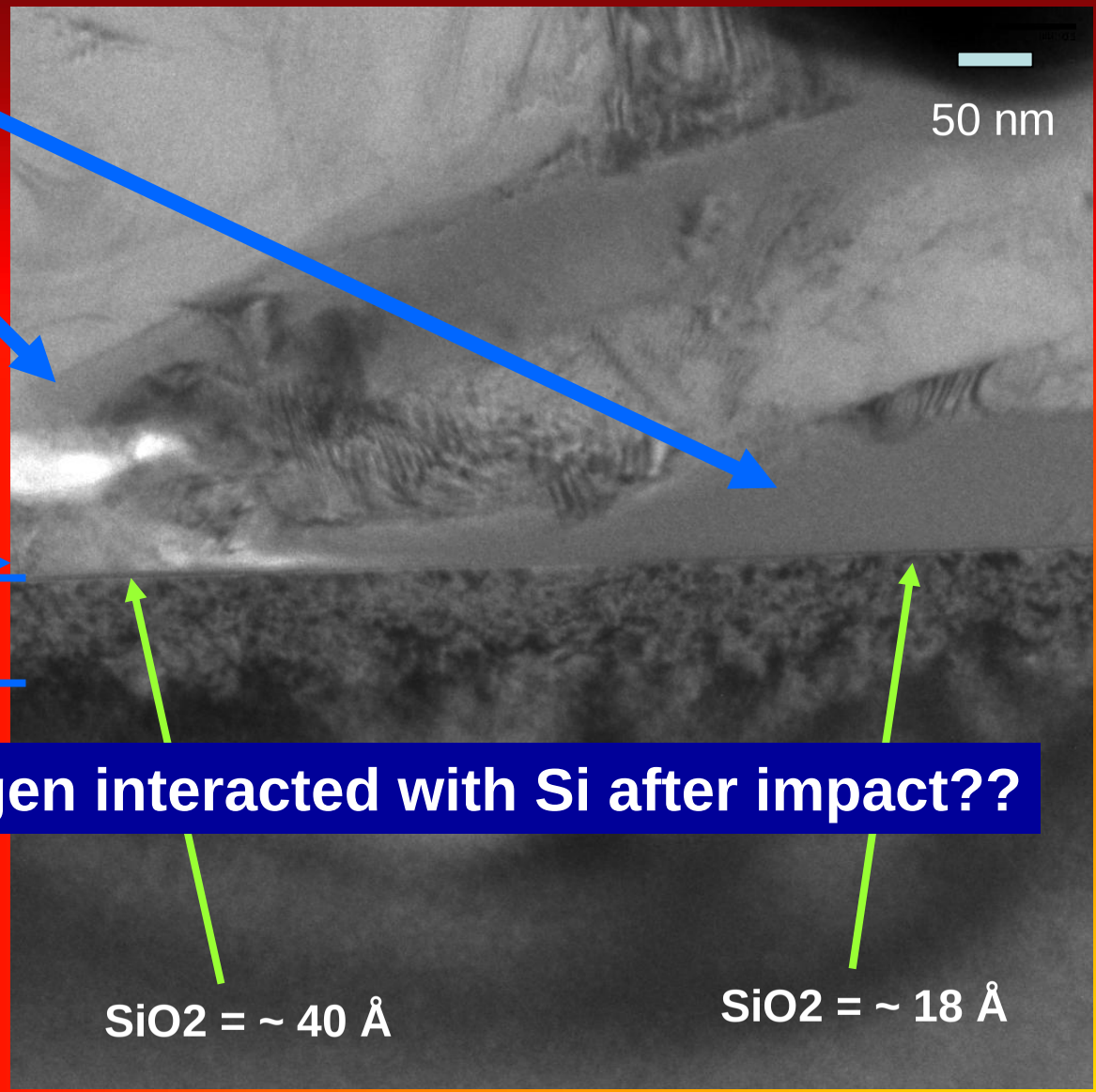


a-Si Particle

c-Si Particle

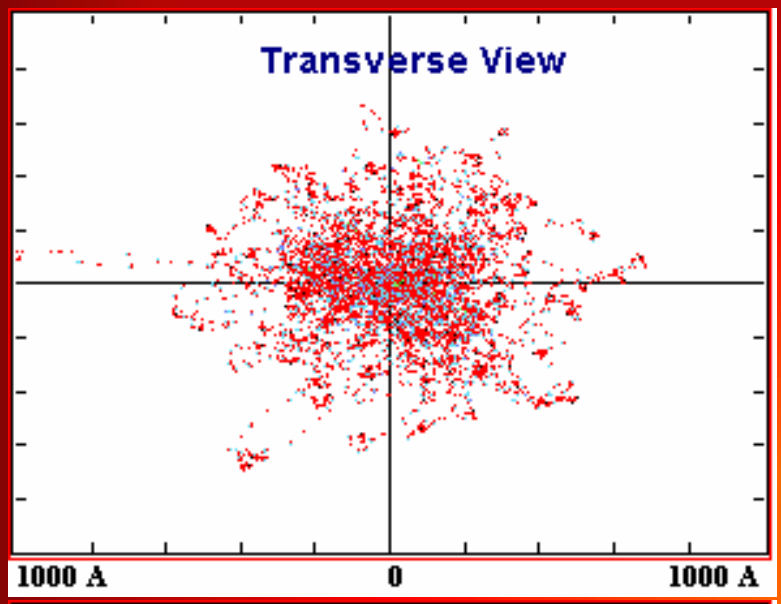
Wafer Surface
Native Oxide Layer

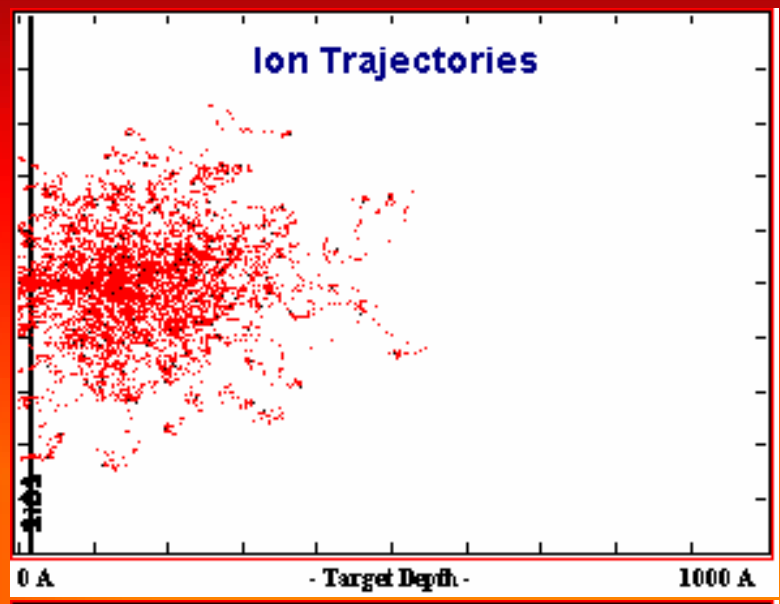
Atmospheric Oxygen interacted with Si after impact??

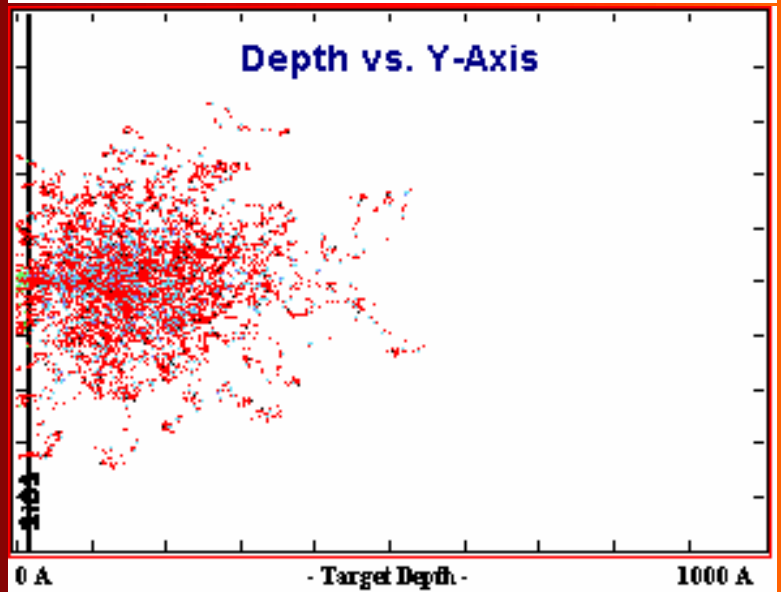
Radiation
Damage Zone

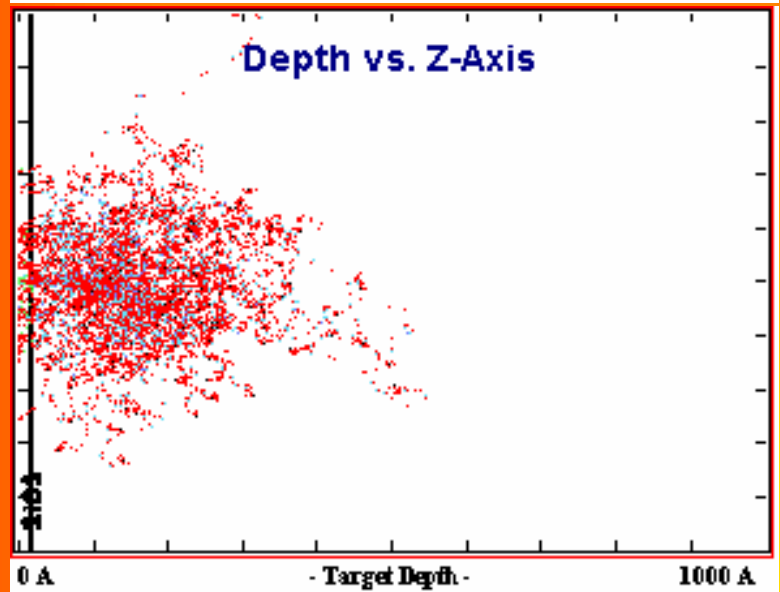
TRIM Monte Carlo Simulation from SRIM-2006

Slow Solar Wind H^+ implantation at 400 km/s

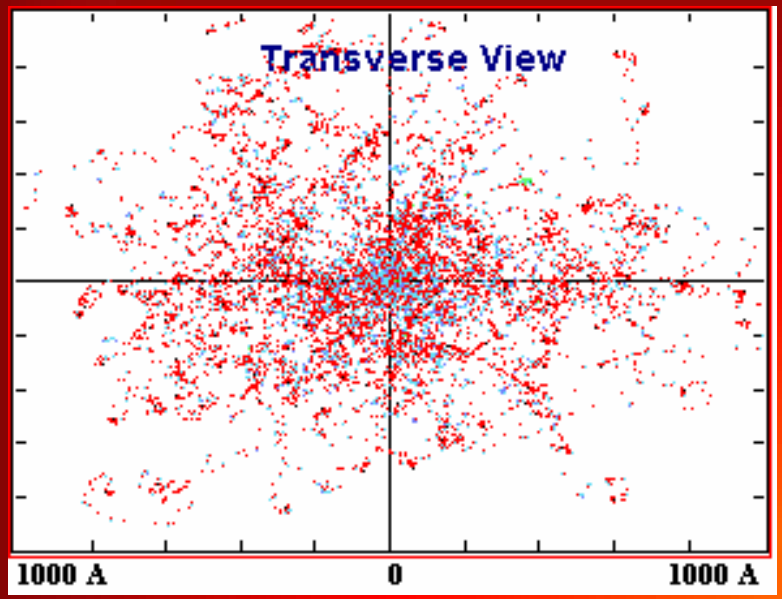


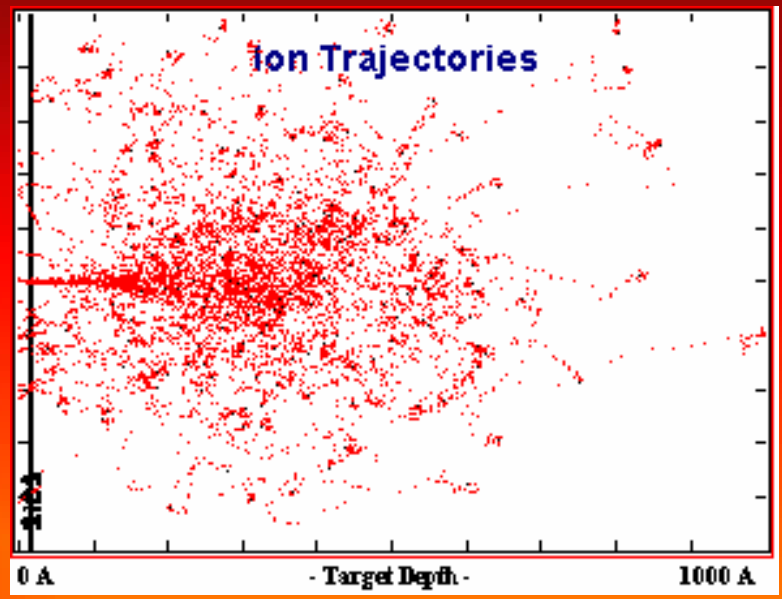


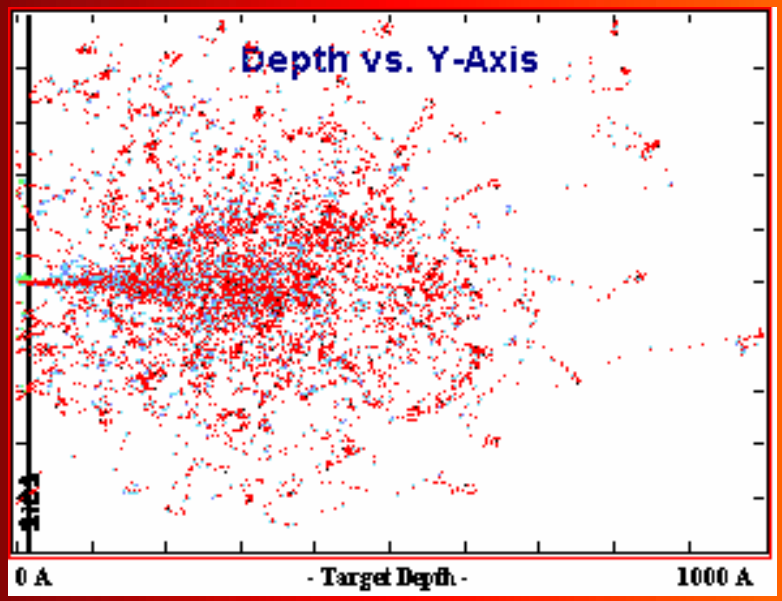


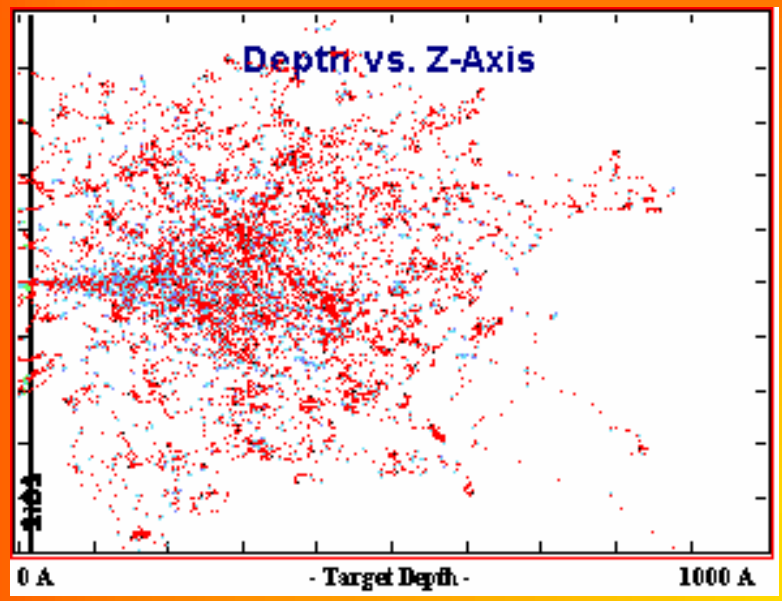


Fast Solar Wind H^+ implantation at 600 km/s

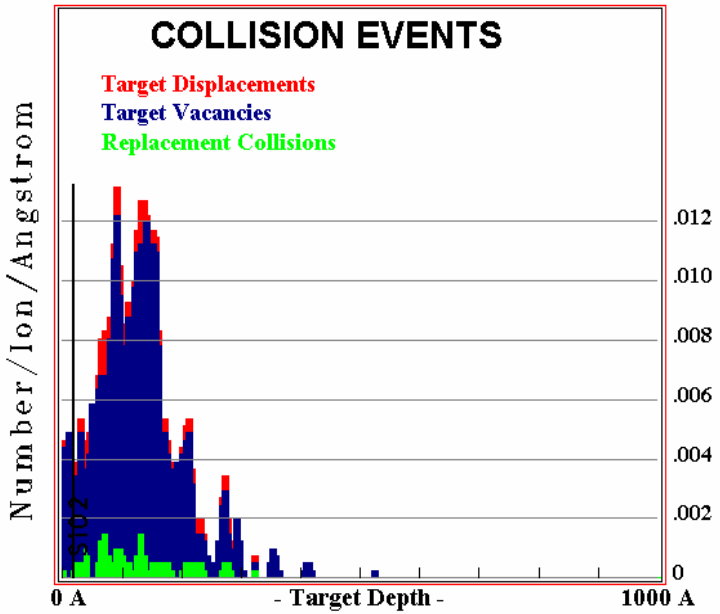


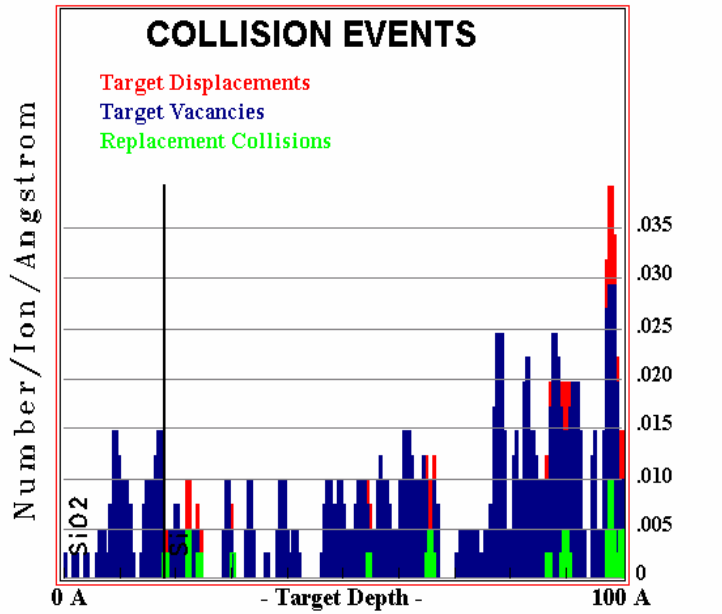




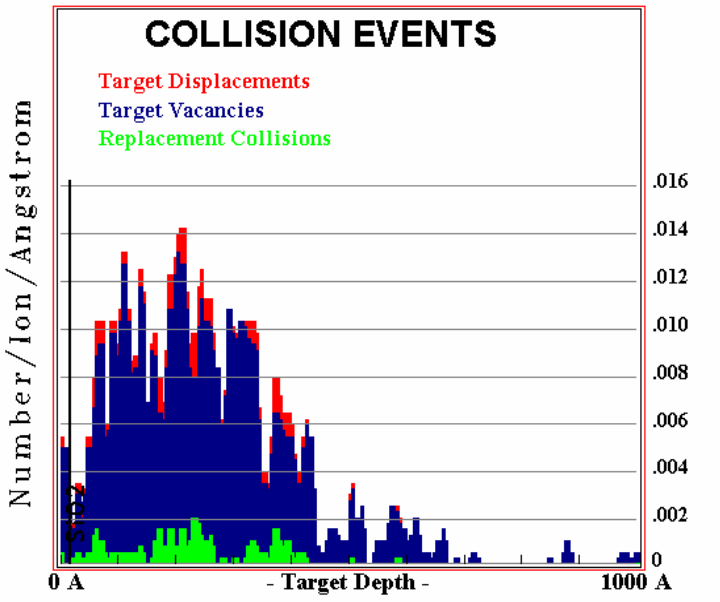


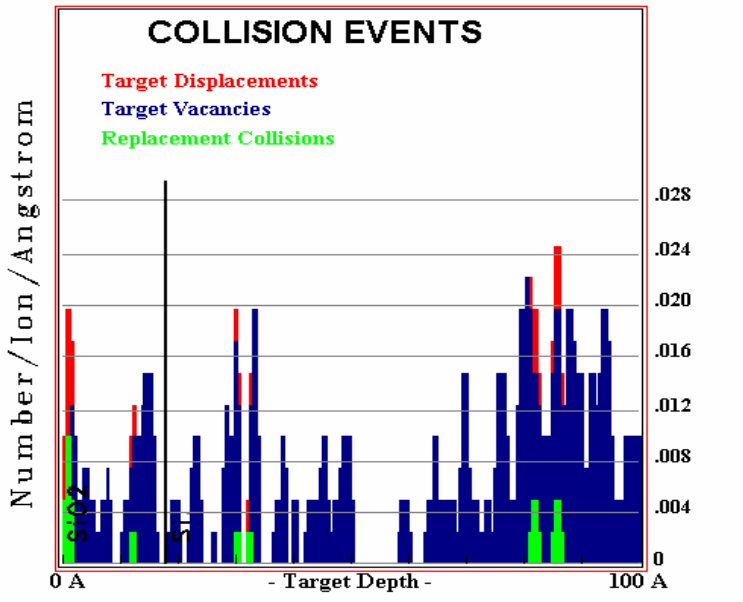
H+ implant
Slow Wind
400 km/s





H+ implant
Fast Wind
600 km/s





Study Results

- No Brown Stain is present and no sign of any other elemental contamination on this sample.
- SiO_2 native oxide layer has grown from ~ 18Å to ~32 to 40Å on this sample.
- Substrate alteration has occurred in the first 604 Å in this sample. Substrate alteration in Si B/C array materials has occurred below the Si/SiO_2 interface to a depth of 592 to 626Å.
- Ellipsometry results are accurate for SiO_2 native oxide layer and for substrate alteration zone (± 10Å conservatively).

Possible Conclusions

- Analysis of elemental abundances must take into account changes in the substrate lattice structure due to solar wind radiation damage that may have occurred throughout the implantation time.
- A radiation damaged native oxide layer may have allowed a reaction between atmospheric oxygen and Si substrate after impact. This caused new growth of the native oxide layer that came to a new equilibrium at 30 to 60Å.
- Should we rethink thin-film contamination on array materials (brown stain hypothesis).